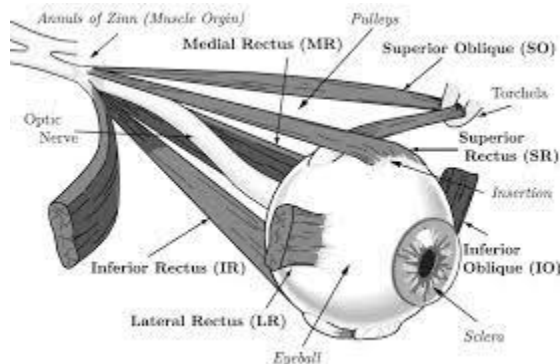


THE MUSCLES BEHIND THE GAZE: ANATOMY AND ELECTROPHYSIOLOGY

A. COURSES



Lateral Rectus Muscle:

The lateral rectus muscle is located on the outer side of the eye within the orbit. This muscle arises from the lateral portion of the common tendinous ring (annular tendon), a fibrous ring encircling the optic nerve that also serves as the origin for five of the seven extraocular muscles, excluding the inferior oblique.

The lateral rectus inserts onto the temporal side of the eyeball, about 7 mm from the corneal limbus, and is roughly 10 mm wide.

Medial Rectus Muscle:

The medial rectus muscle is an extraocular muscle located in the orbit near the nose. It originates from the common tendinous ring and attaches to the anteromedial surface of the eyeball, spanning about 11 mm at the insertion point.

Superior Rectus Muscle:

It originates from the annulus of Zinn and attaches to the anterosuperior part of the eyeball, approximately 8 mm from the corneal limbus, with an insertion width of about 11 mm.

Inferior Rectus Muscle:

The inferior rectus muscle, is located in the orbit near the nose. It arises from the common tendinous ring (annulus of Zinn) and attaches to the anteroinferior surface of the eyeball, about 7 mm from the corneal limbus, with an insertion width of roughly 10.5 mm.

Superior Oblique Muscle:

The superior oblique muscle (obliquus oculi superior) is a spindle-shaped extraocular muscle that originates from the upper, medial part of the orbit, near the nose.

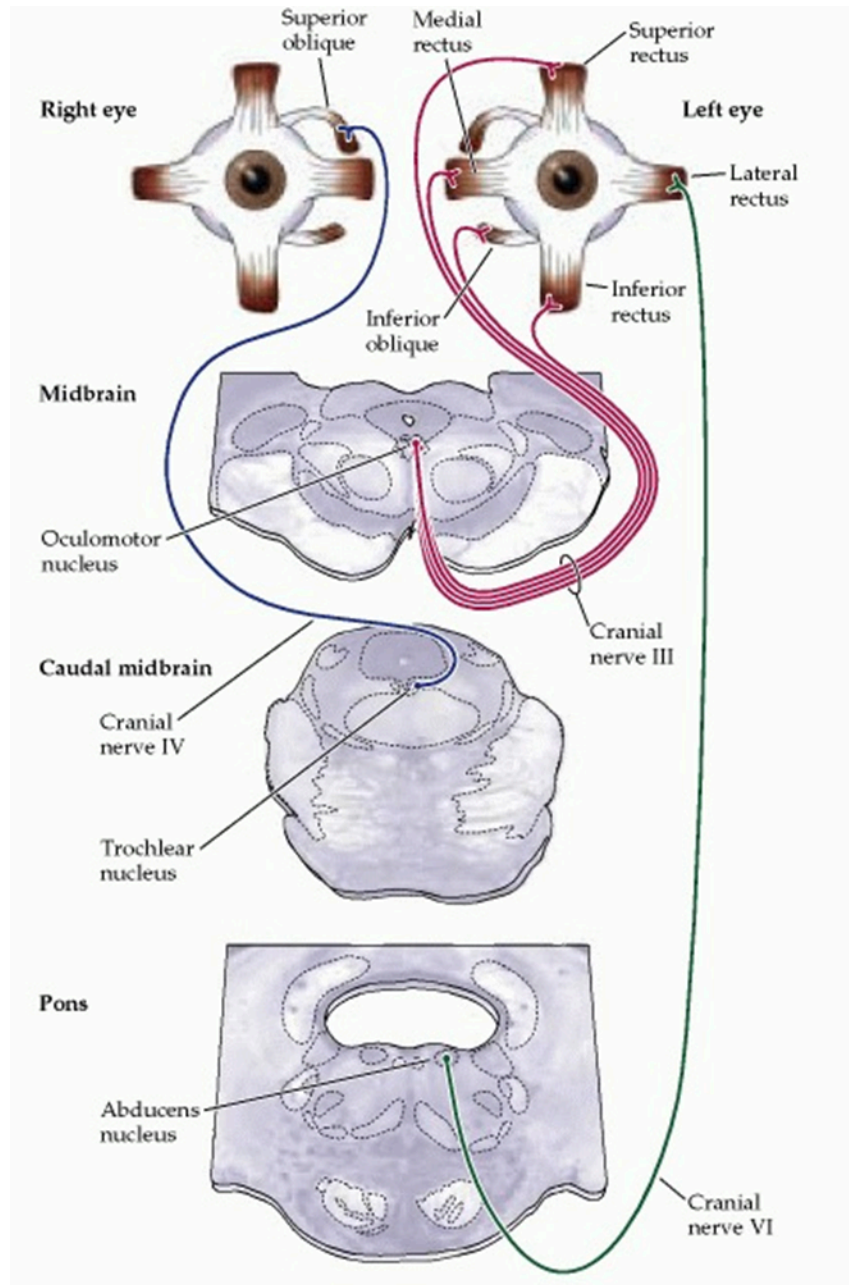
After originating just above the optic foramen and medial to the superior rectus, the superior oblique travels forward and transitions into a tendon. This tendon passes through a fibrocartilaginous pulley, the trochlea, attached to the trochlear fossa of the frontal bone. The tendon, lined with a mucous sheath and fibrous covering, changes direction at the pulley — moving backward, downward, and outward beneath the superior rectus — and inserts onto the sclera on the posterotemporal side of the eyeball, between the superior and lateral rectus muscles. The pulley mechanism allows the muscle to depress the eye despite attaching to its superior surface

Inferior Oblique Muscle:

The inferior oblique muscle (obliquus oculi inferior) is a slim, narrow extraocular muscle located near the front edge of the orbital floor. It originates from the orbital surface of the maxillary bone, next to the lacrimal groove, and attaches to the posterior, inferior, and lateral surfaces of the eyeball. Unlike the recti muscles and the superior oblique, it does not arise from the common tendinous ring (annulus of Zinn).

The muscle courses laterally, backward, and upward, passing between the inferior rectus and the orbital floor, and runs underneath the lateral rectus before inserting into the sclera between the inferior and lateral rectus muscles. In humans, it measures approximately 35 mm in length.

B. NERVE SUPPLY



The extraocular muscles are innervated by lower [motor](#) neurons: the abducens, the trochlear, and the oculomotor.

The **abducens nerve** (cranial nerve VI) exits the [brainstem](#) from the [pons](#)-medullary junction and innervates the lateral rectus muscle.

The **trochlear nerve** (IV) exits from the [caudal](#) portion of the midbrain and supplies the superior oblique muscle. In distinction to all other cranial nerves, the trochlear nerve exits from the [dorsal](#) surface of the brainstem and crosses the midline to [innervate](#) the superior oblique muscle on the [contralateral](#) side.

The **oculomotor nerve** (III), which exits from the [rostral](#) midbrain near the cerebral peduncle, supplies all the rest of the extraocular muscles. Although the oculomotor nerve governs several different muscles, each receives its [innervation](#) from a separate group of lower motor neurons within the third nerve nucleus.

Lateral Rectus Muscle:

It is uniquely innervated by the abducens nerve (cranial nerve VI), whose cell bodies are found in the abducens nucleus of the pons. The nerve fibers travel from the pontomedullary junction, through the cavernous sinus, and enter the orbit via the superior orbital fissure before reaching the medial surface of the lateral rectus.

Medial Rectus Muscle:

The medial rectus is innervated by the inferior division of the oculomotor nerve (cranial nerve III), which sends a branch into the muscle around two-fifths of its length. This branch typically splits into two smaller branches, occasionally three, and further subdivides until the branches are no longer visible approximately 17 mm from the muscle's insertion.

Superior Rectus Muscle:

The superior rectus muscle is supplied by the superior division of the oculomotor nerve from the opposite side's oculomotor nucleus located in the midbrain.

Inferior Rectus Muscle:

The inferior rectus is innervated by the inferior division of the oculomotor nerve (cranial nerve III).

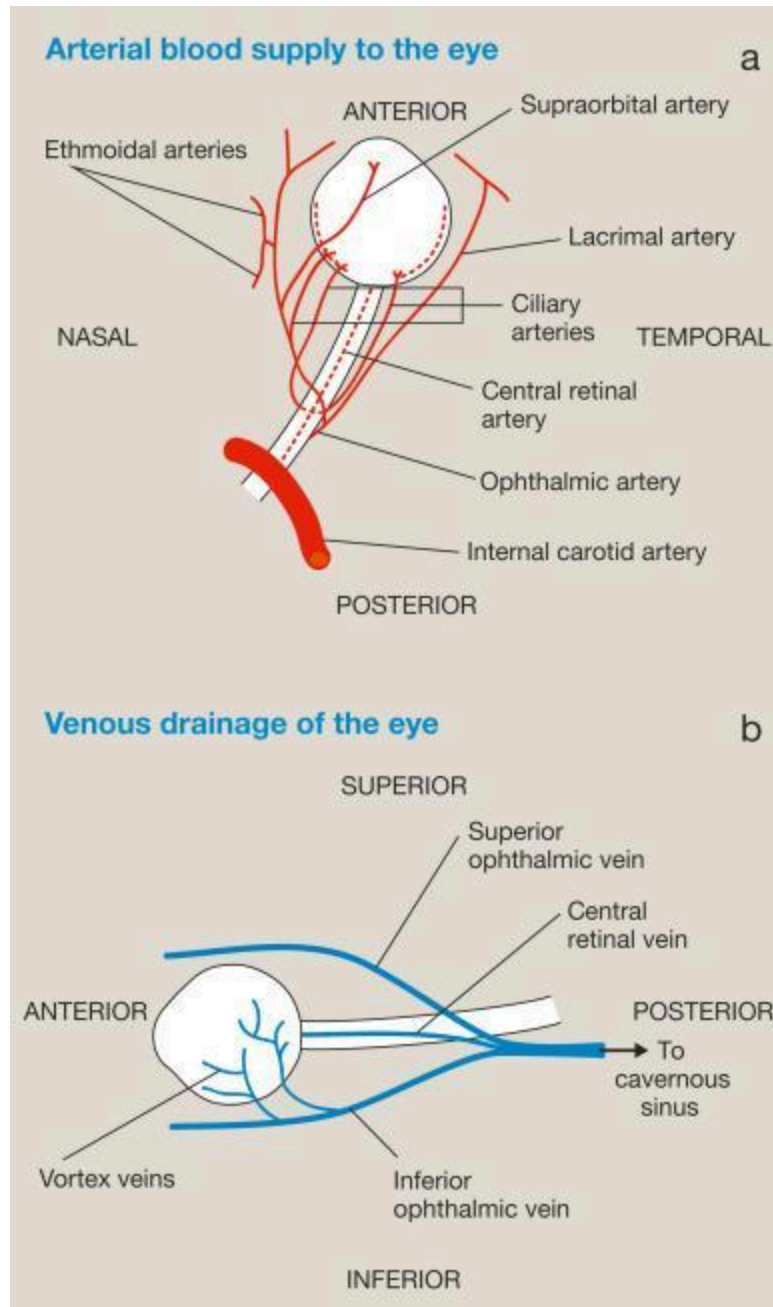
Superior Oblique Muscle:

Uniquely, it is the only extraocular muscle innervated by the trochlear nerve (cranial nerve IV).

Inferior Oblique Muscle:

The inferior oblique is innervated by the inferior division of the oculomotor nerve (cranial nerve III).

C. VASCULAR SYSTEM



Arterial Supply

The extraocular muscles receive their blood supply mainly from the Muscular Branches of the Ophthalmic artery. Additional contributions come from the Lacrimal and Infraorbital arteries.

1. Muscular branches (medial and lateral; or as most will have it -superior and inferior) are direct from the ophthalmic artery that supply the rectus muscles.

The medial muscular branch: supplies the medial rectus, inferior rectus, and inferior oblique.

The lateral muscular branch: supplies the lateral rectus, superior rectus and oblique, and the levator palpebrae superioris.

The superior Muscular Branch: supplies the superior rectus, lateral rectus, superior oblique, and levator palpebrae superioris.

The Inferior Muscular Branch: supplies the medial rectus, inferior rectus, and inferior oblique.

2. Lacrimal artery branch: a branch of the ophthalmic artery that contributes to the blood supply of the lateral rectus.

3. Infraorbital artery: A branch of the maxillary artery that also supplies the inferior rectus and inferior oblique muscles.

4. Anterior Ciliary Arteries: These are vessels that are derived from the muscular branches, that also supply the anterior segment of the eye. The superior, inferior, and medial rectus muscles also receive blood supply via these two anterior ciliary arteries that supply anterior circle of the ciliary body.

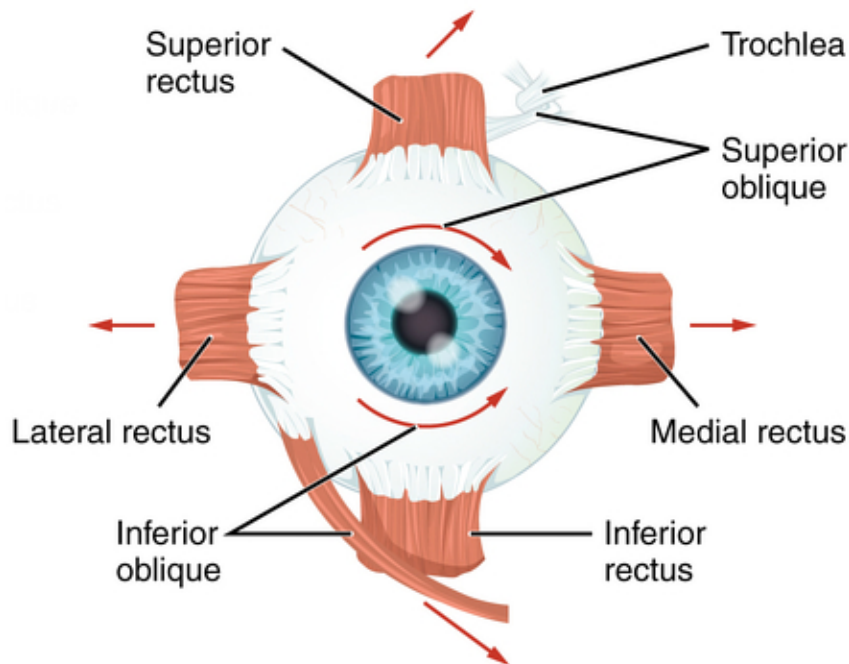
Venous Drainage

The venous drainage of the extraocular muscles is primarily through the vortex veins into the ophthalmic veins:

1. Superior ophthalmic vein: Drains the superior rectus, medial rectus, and superior oblique muscles
2. Inferior ophthalmic vein: Drains the inferior rectus, lateral rectus, and inferior oblique muscles

D. Electrophysiology

I. ACTIONS OF THE EXTRAOCULAR MUSCLES



Anterior view of the right eye

1. Extra-ocular muscles for eye movement have a vertical, lateral or torsional action.

To fully visualize and have a clear concept of such action, Pascal developed the so-called Benzene Ring schematic illustration of muscle activity.

If the ring is considered as an action of the eye as seen from in front of the patient, so that the patient's right is the examiner's left.

- a. **Vertical action** is shown simply by the position of the correspondingly entitled limb of the ring. Thus, the vertical action of superior rectus and IO is elevation.

While that of the inferior rectus and superior oblique can be seen to as depression.

- b. **lateral action** is indicated by the position of the on the limb in relation to the dotted extension of the ring.

The lateral action of the SR for example shows the dot on the limb, so entitled, to be nasal ward of the dotted extension which forks away from

its base. Thus, the lateral action of the superior Rectus is to move the eye nasal ward.

The dot on the limb designated as the S.O. is temporal ward of the dotted line branching from its base, so the lateral action of that muscle is to move the eye temporal ward.

c. **Torsional action** is indicated by the slant of the limb itself

The torsional of the SR and SO is to slant the vertical meridian of the cornea towards the nose, which is intorsion, While that of the IR and IO is extorsion, to slant the vertical meridian of the cornea away from the nose.

The torsional action of the extraocular muscle is depicted by the direction of tilt of the diagonal line going across the correspondingly entitled limbs of the ring.

2. In addition, the ring indicates the field of fixation in which the particular muscle exerts greatest vertical action.
 - a. So that the inferior rectus IR shows it most marked depressive effect When the eye turned out.
While the superior Oblique shows the most marked vertical effect (depressive) when the eye is turned in.
 - b. Six cardinal position of gaze (and their corresponding primary extra-ocular muscle action.

MOVEMENT	RIGHT EYE	LEFT EYE
Right	Right lateral Rectus	Left medial Rectus
Up and Right	Right superior rectus	Left inferior oblique
Down and Right	Right medial Rectus	Left superior oblique
Left	Right medial Rectus	Left lateral rectus
Up and left	Right inferior oblique	Left superior rectus
Down and left	Right superior oblique	Left inferior rectus

The Organization of Associated and Antagonistic innervations

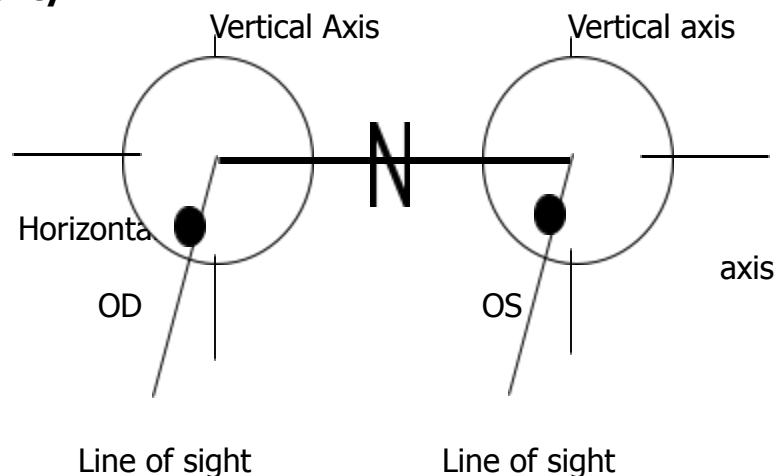
3.
 - a. Synergists- for a given movement s, in same eye, occupy the same relative position on the ring. As the
S.R and I.O for elevation, and the IR and so for depression.
 - b. Antagonists are shown by their relative positions. As the S.R and IR for vertical movements.
SR and SO for lateral movement, or SR and IO for torsional.

- c. Yoked muscles of the 2. eyes occupy identical limbs on the rings for both as the SR of the right eye ring and the IO of the left eye ring.
- d. Cross antagonists comprise the antagonists of the yoked muscles, as the SR of the right eye and the S.O. of the left eye.
- e. The fundamental law of ocular movements, Herings law states that both eyes are equally innervated during ocular movement and that two yoked muscle of the two eyes, when performing a conjunctive or disconjunctive movement, receive equal innervation.
- f. another law that reflects the activity of the ocular muscle is Sherrington law that states-Whenever change occur in the innervation to an extra ocular muscle a proportionate but opposite change of innervation occurs in the antagonist.
- * There is a reciprocal innervation to antagonistic muscles.

INNERVATION & INNERVATION CONTROL

A combined appreciation of the Herings law and Sherrington's law. Chavasse (1939) stated that if the eyes are to work together smoothly and promptly during voluntary ocular rotations, not only must certain muscles be innervated to produce the desired exertion (moot) of the globe, but other muscle (antagonists) must receive, a positive innervation. The extra ocular muscles are striated muscles and like striated muscles elsewhere in the body, is maintenance in a constant state of terms that iss reflex in origin.

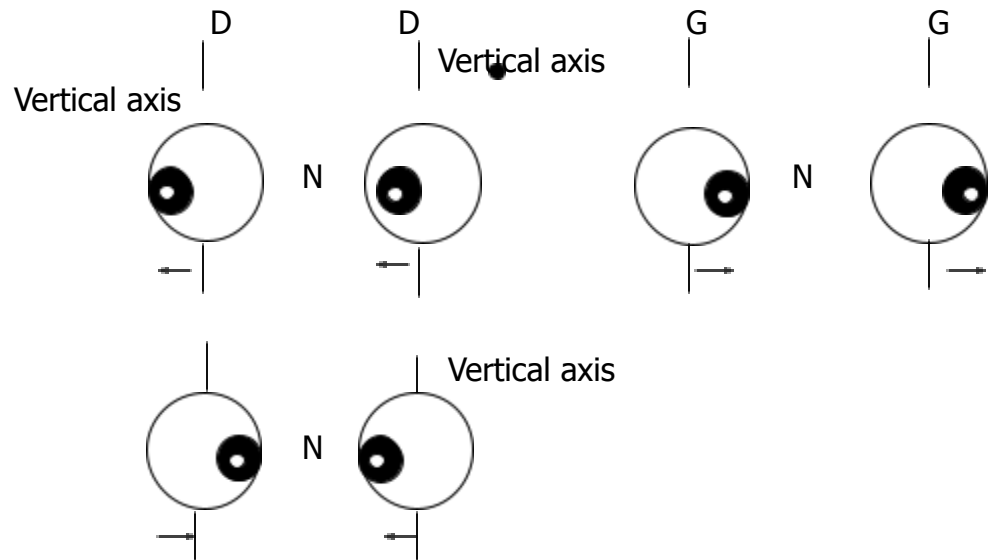
II Ocular Motility:



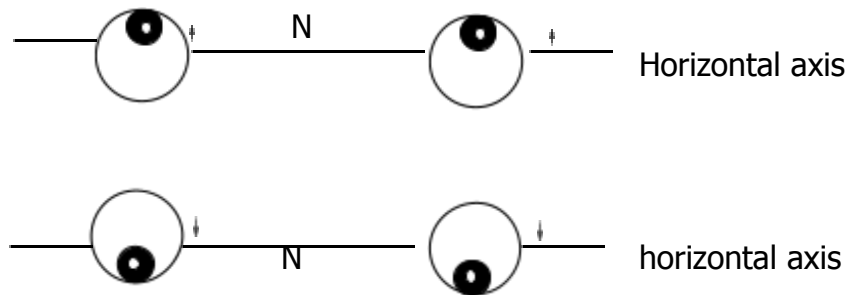
Movement of the eyeball can be described as a rotation of the eye around any of the three axes .

- A. A movement of the eyes to either sides or towards each other constitutes a movement around a vertical

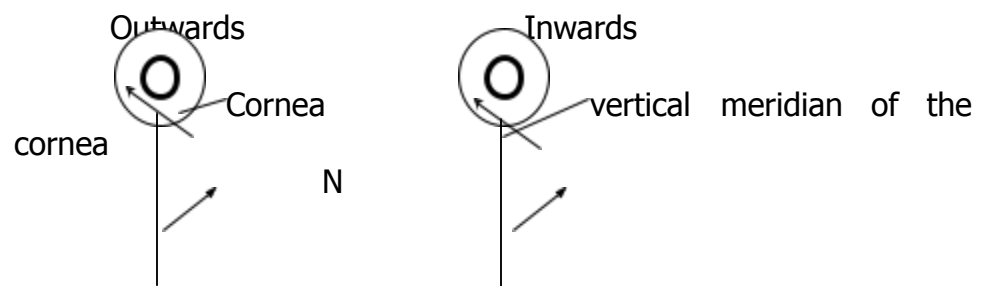
axis which is perpendicular to the primary horizontal plane.

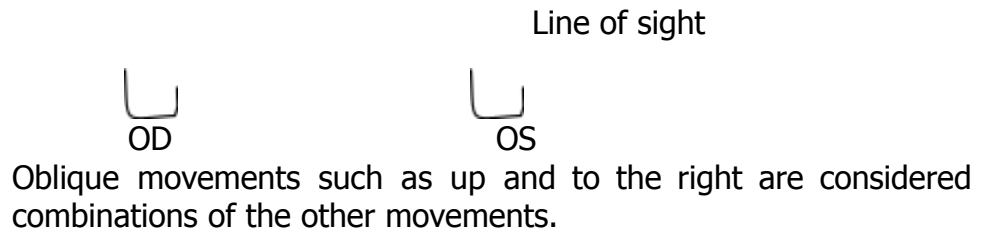


- B. A movement of the eyes up or down constitutes a rotation around a horizontal axis which is perpendicular to both the line of sight



- C. A rotation of the vertical meridian of the cornea (such as the top of the eye outwards while the bottom rotates inwards). Known as a torsional movement, is a rotational of the eye around an axis which is the line of sight.





Torsion is a normal physiological component of ocular movement. It is measured by utilizing straight forward position of the line of sight and the horizontal meridians of the eyes. The horizontal meridional plane of the eye coincides with the plane of regard. When the line of sight is straight forward, the non-fixating eye is occluded, accommodation is relaxed, and the head is held with the base line horizontal and the face plane vertical. The amount of torsion corresponds to the dihedral angle between the horizontal meridian and the plane of regard.

CLASSIFICATION:

- A. Extorsion or abtorsion: - If top of eye turns out
- B. Intorsion or addorsion: - If top of eye turns in
- C. Levotorsion: - If top of eye turns towards subject's left.
- D. Dextrotorsion; - Is towards subject's right.
- E. Positive: - If top of eye turns the same way as the hands of a clock, which the subject is watching turn.
- F. Negative: - If top of eye turns opposite to the way the hands of a clock, which the subject is watching turn.
- * The eye exhibits intorsion when turned up and out or down and in and extorsion when directed up and in or down and out.

E Specifications of the Direction of Regard

Alpern gave the following definition of the elements:-

- * Concerned in fixation
- a. Entrance pupil
The image of the real pupil found at the cornea.
- b. Object of Regard.
The point towards which the observer directs his gaze.
- c. Line of sight.
The line from the centre of the entrance pupil to the object of regard.
- d. Visual axis
The combination of two parallel lines.

In image space, one from the fovea to the second nodal point. In object space, one from the object of regard on the first nodal point.

e. Papillary Axis

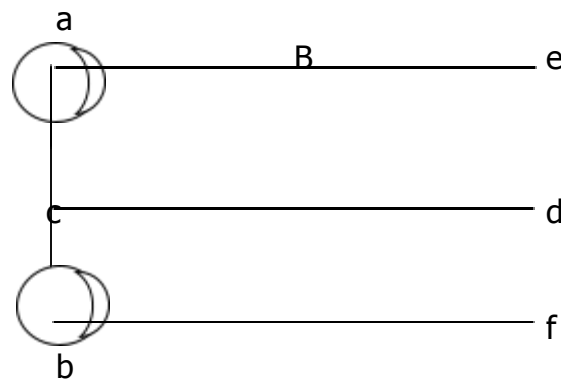
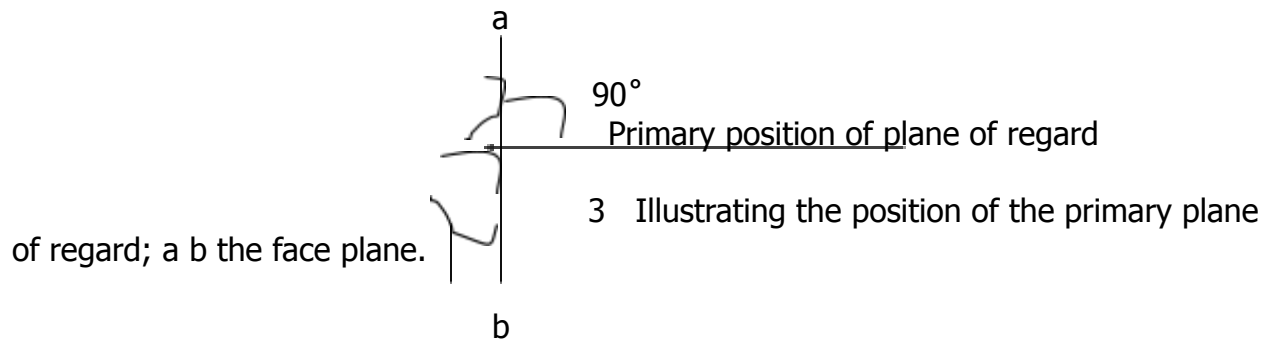
The line from the centre of the entrance pupil which is normal to the cornea, i.e. which passes through the centre of curvature of the cornea.

f. Angle Lambda

The angle at the centre of the entrance pupil created by intersection of the papillary axis and the line of sight.

g. The centre of Rotation

The point which during rotation of the eye has zero velocity, both within the eye and within the orbit. It is usually located 13.5mm behind the cornea when the eye is in the straight forward position.



Illustrating the ahead position of the lines of sight a and b centre of rotation of the two eyes a, b the base line; a,b,f,e the plane of regard (in primary position), c d the primary sagittal lines; a e and b f the lines of sight.

h. Base Line:

The line connecting the centre's of rotation of the two eyes.

i. Plane of regard:

The plane which includes both the Base line and the object of

regard

- j. Face plane:
The plane tangent to the chin and two superciliary ridges.
- k. Primary position:
The plane perpendicular to the face plane.
- l. Primary Sagittal line:
The line in the primary position of the regard which bisects the
base line.
- m. Straight forward position of the line of sight:
The line of sight is said to be in its straight forward position when it is parallel to the primary sagittal line. Since this is the position ordinarily used during the various testing procedures, except as otherwise noted, it constitutes the chief point of reference for of the ocular movements.

In of right is perpendicular to the both base line and the face plane.

F DUCTION (Monocular Rotations)

A movement of one eye only is properly known as duction.

Ductions are classified in accordance with the direction in which the eye is moved as follows:-

- A. Lateral
 - 1. Adduction:- The eye turns towards the nose
 - 2. Abduction:- The eye turns away from the nose
- B. Vertical
 - 1. Supraduction;- The eye turns up
 - 2. Infraduction: - The eye turns down
- C. Torsional
 - 1. Plus or encyclocloduction:- The top of the vertical axis of the cornea turns in
 - 2. Minus or excyclocloduction: - The top of the vertical meridian of the cornea turns out.

G VERSION (Parallel movements)

When the attention is directed towards an object which did not lie on the lines of sight of both eyes, so that its images were not on either fovea, and the lines of sight are moved an equal amount in the same direction in order to fixate the object.

Or when an object already so that both lines of sight must turn together in the same direction refixates it, the movements are known to version.

These yoked or conjugate movements may be voluntary or involuntary. It will be observed, that even if one eye is occluded, it will move in accompaniment the fixating eye.

Versions is classified as follows:-

- A. Lateral:- In which internal rectus or adductor of one eye is linked with the external rectus or abductor of the other.
 - 1. Dextro:- meaning to the right
 - 2. Sinistra or levo:- meaning to the left.
- B. Vertical:- In which the identical vertical muscles of both eyes are linked.
 - 1. Ana,supra:- (or elevation) both eyes up.
 - 2. Kata,infra:- (or depression) both eyes down
- C. Torsional: In which the vertical axis of the cornea rotates about the line of sight.
 - 1. Dextrocylo:- The tops of both vertical axis rotate to the up
 - 2. Levocylo:- The tops of both vertical axis deviate to the left.
 - * Compare yoked muscle and
 - * Vertical version /in non parallel movement.

H VERGENCE (Non-parallel or Disjunctive Binocular movement)

- * If an object is presented to two eyes on the primary sagittal line but not intercepting the line of sight of either eye, the two eyes will make a movement to place the object on both line of sight.
- * If the lines of sight were directed towards the distance and the object is nearby, the rotation of the eyes necessitated will be in opposite directions, the right eye turning towards the left and the left eye towards the right. Such a movement from parallelism is known as a vergence with any torsion.
- * Vergence movements were also defined as those which change the angle that the intersecting lines of sight of the two eyes form with each other.
- * When the lines of sight converge to a point in front of the eyes, they deviate inwards, and are said to be converging. The conjugation is b/w the internal recti of both eyes. When the lines of sight appear to diverge from a point behind the eyes, they deviate outward, and are said to be diverging.
- * The conjugate Encyclovergence here is b/w the external rectus of both eyes. Diverging , is also often applied when the lines of sight deviate from a greater angle of convergence to a lesser one.

Vergence are classified as follows:-

- A. Lateral:

1. Convergence:- When the lines of sight meet at a point in front of the eyes or the angle. So formed is increased.
 2. Divergence:- When the lines of sight meet at a point behind the eyes, or the angle of convergence is decreased.
- B. Vertical:- When the lines of sight of one eye is directed upwards and that of the other is depressed.
1. Right supra-vergence or sursum vergence; left infra-vergence or deosum-vergence. (commonly called right supraduction or left infraduction).
In which the line of sight of the right eye is at a position above that of the left eye.
 2. Left supra-vergence or sursum vergence right infra-vergence or deosum vergence.(commonly called left supraduction or right infra-duction-reverse of the above).
- C. Torsional:
1. Encyclovergence or conclination-in which the vertical axis of the corneas intersects above the eye.
 2. Excyclovergence or declination-in which the vertical axis of the corneas intersects below the eye.

ASSOCIATED & CONJUGATED MOVEMENTS

1. The SR and IR are inserted 27° and the oblique at 51° to the anterior-posterior axes of the eye.
These angular insertions give a torsional effect (and more with obliques).
2. For external and internal recti, it is assumed that the insertion of each of symmetrical to the horizontal plane of the eye.
Their vertical axis line in the equatorial plane of the eye. A rotation around these axes is not associated with any torsion (in the one degree position).
3. The angles of the orbit and the angles transversed by the long axis of the various muscles in traveling from their origins to their insertion affect the action of each muscle in respect to the position of the eye when in the one degree and when it is turned in any two degree position.
4. The rules governing the action of a muscle when the eye is in the one degree position do not necessarily explain its action when the eye is rotated either laterally or vertically.
In the one 1° position, the External Rectus and Internal Rectus effect only simple Lateral version of the eye.

If the eye is turned to the left or right, they still effect lateral movements,
But if elevated or depressed, they provide vertical and torsional effect, in accordance with the direction in which the eye is turn.

If elevateral, ER provide Supraduction and will add to the Intorsion
If elevateral, MR provide Supraduction and will add to the Extorsion
If depressed ER provide Infraduction and will add to the Extorsion
If depressed MR provide Infraduction and will add to the Intorsion

ASSOCIATED MOVEMENT

Lateral

In the primary position, the Lateral Rectus and medial Rectus are the only muscle involved in the lateral movement of the eye because line in the equatorial plane. Rotation around the axis is not associated with torsional movement.

Adduction and abduction can b/4 be brought about by one single muscle, the internal rectus and external rectus respectively.

VERTICAL MOVEMENT

For the eye to perform vertical movement, the movement is about a horizontal axis

For elevation: The SR and its synergist IO are contracted.

Elevation of SR is associated with adduction and extorsion elevation of IO is associated with abduction and intorsion.

In their effort to rise the eye, SR and IO are synergist; and in the lateral and torsional, they are antagonists.

The associated antagonistic action concell out.

In the same manner the lowering of the eye is brought about by the associated action of the inferior rectus and so.

The oblique contribute 3/10 of the energy needed for vertical movements.

Innervation to elevate

SR----- elevation

IO-----elevation

SR Elevation not associated with addition Extorsion b/c of IO.

CONJUGATION MOVEMENTS

Certain muscle or group of muscle s are so linked in their movement that it is impossible to use those in one eye without using the corresponding muscle in the other eye. Such muscle are conjugated muscles and such movement conjugated movement.

Example : the upward movement of the eye are conjugated movement. It is an impossibility to raise one eye without raising the other.

VARIOUS CONJUGATIONS:

The number of these conjugated movement is large and various from one investigator to another that are obvious and do not pose any controversy.

1. Elevation SR & IO of both Eyes
2. Depression IR & SO of both eyes
3. Dextroversion RLR & LMR
4. Levoversion RMR & LLR
5. Non-parallel movements: (1) convergence MR of OU
(2) less convergence LR of OU (divergence)

The 1st 4 are parallel movements and are reached voluntarily even in the dark.

The 5th while occurring in both eye simultaneously causes the eye to move in opposite direction.

Nevertheless, these opposite movements are conjugated from an innervation part of view.